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EP 0223585 A2 US 4764434 A

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(54) Wear resistant tools

(57) Wear resistant rotary machining tools comprising a body of cemented tungsten carbide having a layer of abrasive polycrystalline diamond or cubic boron nitride compact bonded to a convex curved surface of the tool body, and also bits comprising a layer of abrasive compact of uniform axial thickness extending over the whole top surface of the tip of the drill bit.

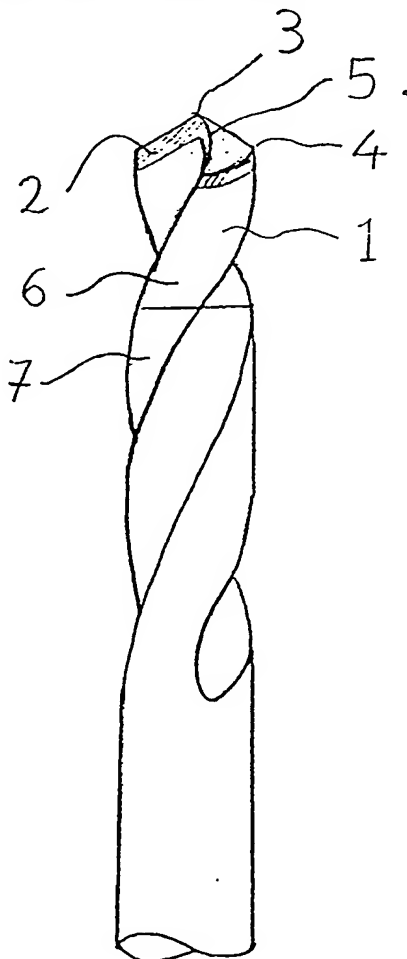


Figure 5

1/4



Figure 1

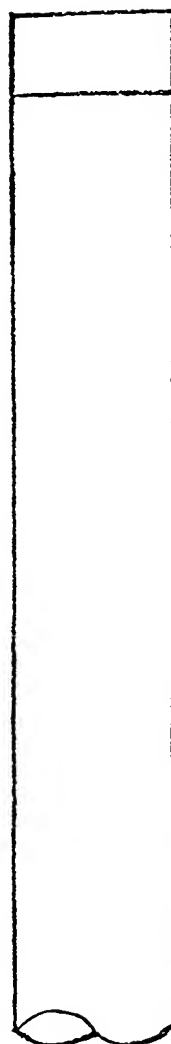


Figure 2

2/4



Figure 3



Figure 4

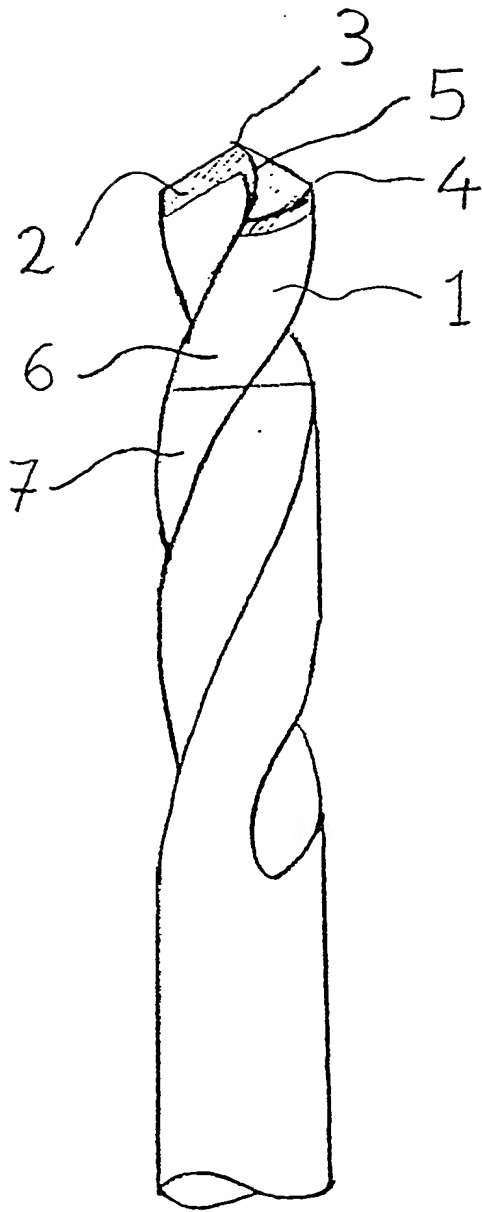


Figure 5

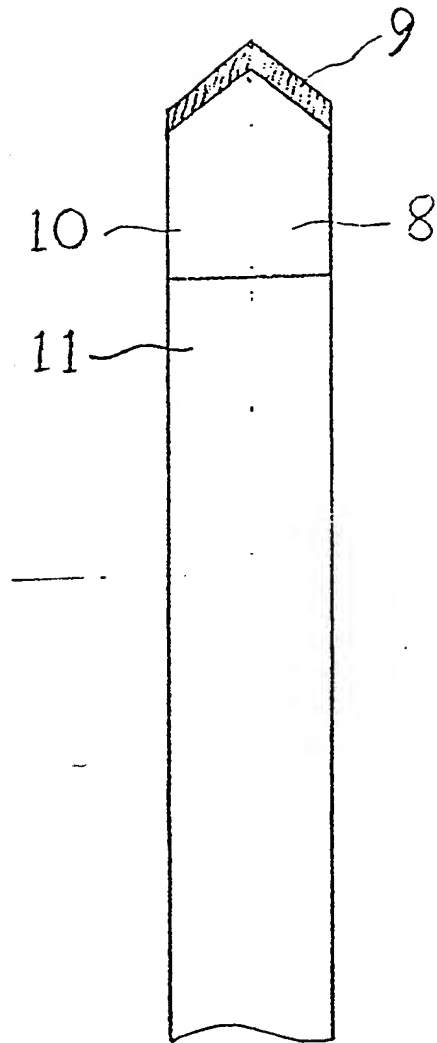


Figure 6

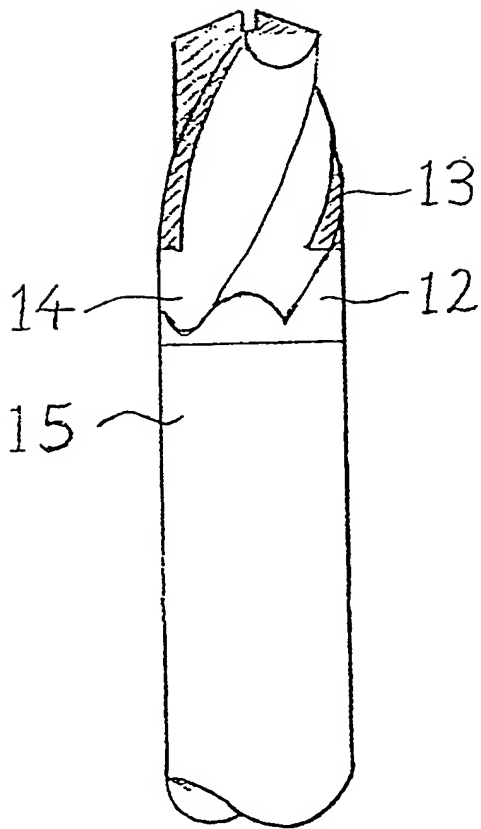


Figure 7

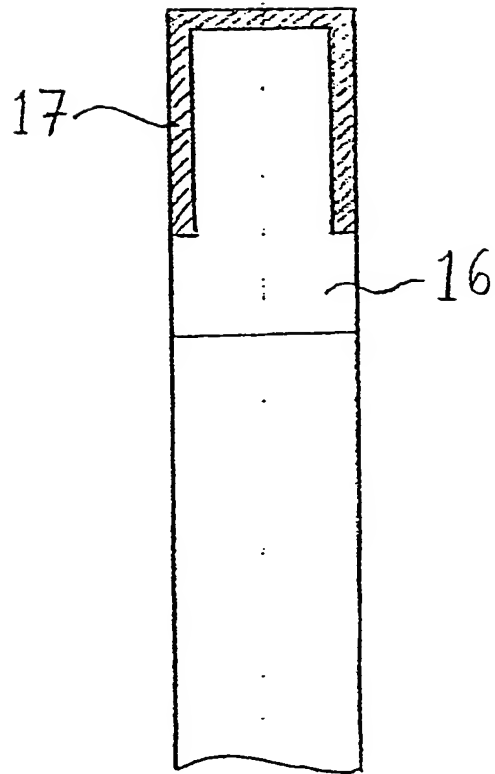


Figure 8

WEAR RESISTANT TOOLS

This invention relates to wear-resistant tools for cutting and drilling and in particular to wear-resistant rotary cutting tools for machining metals and other materials.

Almost every product made by the engineering industries requires at some stage in its manufacture the machining of metals or other materials. Typical machining operations include drilling, milling, reaming, thread cutting, slot cutting, and turning. Typically, these operations are carried out by automated machine tools which are fitted replaceably and often interchangeably with tool bits such as drill bits, end mills, thread taps, slot drills and reamers. The preferred shapes of the various cutting tools are well known in the art and will not be described further here.

The material from which the cutting tools are made must combine as far as possible the properties of resistance to deformation (hardness), resistance to fracture (toughness), and resistance to wear (durability). The most widely used materials for this purpose are steel and tungsten carbide. However, both steel and tungsten carbide are prone to wear in the operating environment and as a result cutting tools made of these materials need to be removed for sharpening or replacement quite frequently. The expense of sharpening or replacing the steel or tungsten carbide tool bits, and the machine tool downtime that is needed for their frequent replacement, add considerably to the total cost of the manufacturing process and interfere with the smooth operation of production lines.

Abrasive compacts are also well known in the art and are used extensively in industry for the abrading of various workpieces. They consist essentially of a mass of abrasive particles present in an amount of at least 70 percent, preferably 80 to 90 percent, by volume of the compact bonded into a hard conglomerate. Compacts are polycrystalline masses and can replace single large crystals in many applications. The abrasive particles of compacts are

invariably ultra-hard abrasives such as diamond and cubic boron nitride. Compacts containing diamond abrasive particles are known in the art by the initials PCD. Compacts containing cubic boron nitride abrasive particles  
5 are known as PCBN.

Abrasive compacts generally contain a second phase or bonding matrix which contains a catalyst (also known as a solvent) useful in synthesising the particles. In the case of cubic boron nitride, examples of suitable catalysts are  
10 aluminium or an alloy of aluminium with nickel, cobalt, iron, manganese or chromium. In the case of diamond, examples of suitable catalysts are metals of Group VIII of the Periodic Table such as cobalt, nickel or iron or an alloy containing such a metal.

15 As is known in the art, diamond and cubic boron nitride compacts are manufactured under conditions of temperature and pressure at which the abrasive particle is crystallographically stable.

Abrasive compacts may be bonded directly to a tool or  
20 shank for use. Alternatively, they may be bonded to a backing such as a cemented carbide backing prior to being mounted on a tool or shank. Such backed compacts are also known in the art as composite abrasive compacts.

The backing will typically be made of cemented carbide  
25 such as cemented tungsten carbide, cemented tantalum carbide, cemented titanium carbide or a mixture thereof.

Hitherto, machining tools comprising PCD or PCBN cutting edges have generally been made from flat pieces of PCD or PCBN or their composites. Tools with more complex  
30 shapes have generally been made by brazing flat pieces of PCD or PCBN/tungsten carbide composite onto tungsten carbide tool bodies followed by machining the body and composite together to form the desired tool. The limitations that result from using a planar geometry for the PCD layer can  
35 readily be appreciated by considering the case of the most widely used machining tool: the twist drill bit.

At present, standard twist drill bits having PCD or PCBN cutting surfaces are mainly of two types, as described

in U.S. Patents Nos. 4679971 and 4527643. In the first type, a solid disc of PCD or PCBN/tungsten carbide composite is brazed to the tip of a coaxial tungsten carbide shank of similar diameter, resulting in a cylindrical blank tipped at one end with a thin layer of PCD or PCBN. This blank is then machined to the desired drill bit shape. Since the tip of a standard drill bit is preferably pointed with a tip angle of approximately  $118^\circ$ , it follows that drill bits made in the above way are characterised by a PCD or PCBN layer at the cutting edge whose thickness decreases linearly with increasing distance from the rotary axis of the drill bit. Typically, the PCD or PCBN layer near to the distal edge of the tip is extremely thin and therefore relatively weak. Furthermore, resharpening the tool will remove this thin layer entirely.

Drill bits of diameter greater than 5 mm are generally furnished with PCD or PCBN cutting edges by forming a suitable blank of cemented tungsten carbide or similar material, cutting one or more slots into the tip of the blank, and brazing one or more flat pieces of PCD or PCBN/tungsten carbide composite into the slot or slots, followed by machining the blank and inserts jointly to form a drill bit with cutting edges composed of PCD or PCBN. This method of manufacture is expensive. Furthermore, drill bits made in this way are characterised by a non-ideal tip configuration imposed by the flat PCD or PCBN insert. The cutting edges are at the wrong angle and not properly aligned relative to each other, which results in uneven machining and excessive heat generation. The imperfect tip configuration interferes with the removal of swarf.

Drill bits with diameters greater than 5 mm made by the processes described above are currently in use. Their superior wear resistance outweighs their cost and disadvantageous properties. Typically, holes are drilled initially with a PCD or PCBN tipped drill, which drills unevenly for the reasons set out above, and the holes are then given a smooth finish with a conventional steel or tungsten carbide drill.



United States patent No. 4713286 discloses twist drills in the diameter range 0.15-3.2mm for use in printed circuit board manufacture. These drills are machined from drill blanks, which blanks comprise one or more veins of PCD  
5 or PCBN bonded *in situ* to a cemented tungsten carbide body, the veins of PCD or PCBN positioned to extend longitudinally from the conically shaped point region of the drill blank. Once again the machining required to form the twist drill is complex, and the twist drills provided in this way have non-  
10 ideal tip configurations because the cutting edges on opposite sides of the drill tip are not aligned.

The absence of satisfactory PCD or PCBN tipped drills and other rotary cutting tools represents a serious and long-felt deficiency in machine tool technology in view of  
15 the outstanding importance of rotary machining operations in most manufacturing processes.

Accordingly, it is an object of the present invention to provide twist drill bits having cutting edges of PCD or PCBN with improved cutting properties, improved toughness  
20 and improved durability relative to existing cutting tools of this type.

It is a further object of the present invention to provide slot drills, end mills, thread taps and reamers having the advantageous properties listed above.

25 It is a further object of the present invention to provide methods of manufacturing the twist drill bits, slot drills, end mills, thread taps and reamers according to the present invention.

The present invention provides twist drill bits  
30 comprising a layer of PCD or PCBN of substantially uniform axial thickness extending over substantially the whole top surface of the tip of the drill. The PCD or PCBN layer is bonded to a drill body comprising cemented tungsten carbide, cemented tantalum carbide, cemented titanium carbide or  
35 similar materials. The body may comprise two or more pieces joined together by brazing or other means. The thickness of the PCD or PCBN layer is typically between 0.1 and 2.0 mm and preferably between 0.5 and 1.5 mm.

The present invention further provides a slot drill, end mill, thread tap or reamer comprising a layer of PCD or PCBN bonded to a convex curved surface of a tool body, the layer being shaped to provide a cutting edge composed of PCD or PCBN.

The tool body may comprise cemented tungsten carbide, cemented tantalum carbide, cemented titanium carbide or similar materials. The tool body may comprise two or more pieces joined together by brazing or other means. The thickness of the PCD or PCBN layer normally does not exceed 2.0mm.

The present invention further provides a method of manufacturing a twist drill bit comprising the following steps: providing a drill blank body having a conical tip; fabricating a drill blank by bonding a layer of PCD or PCBN to substantially the whole surface of the conical tip, said layer having substantially uniform axial thickness; and machining the drill blank to form the twist drill bit. Once again, the drill blank body may comprise steel or tungsten carbide or tantalum carbide or similar materials. The thickness of the PCD or PCBN layer is preferably 0.5 to 1.5mm.

The present invention further provides a method of manufacturing a slot drill, end mill, thread tap or reamer comprising the following steps: providing a suitably shaped tool blank body; fabricating a tool blank by bonding a layer of PCD or PCBN to a convex curved surface of the body; and machining the tool blank to form the slot drill, end mill, thread tap or reamer.

Certain embodiments of the invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a twist drill bit made according to the above-described present method for making twist drill bits of diameter 5 mm or less having a cutting edge of PCD or PCBN. The part of the twist drill bit that is composed of PCD or PCBN is represented by hatching.

Figure 2 is a cross-section through one of the drill

blanks from which the twist drill bits of Figure 1 are machined.

Figure 3 is a twist drill bit made according to the above-described present method for making twist drill bits of diameter greater than 5 mm having a cutting edge composed of PCD or PCBN.

Figure 4 is the blank into which a PCD or PCBN/tungsten carbide insert is brazed in the method of making the twist drill bits of Figure 3.

Figure 5 is a standard twist drill bit according to the present invention.

Figure 6 is a cross-section through a drill blank from which the twist drill bit of Figure 5 is machined in a manufacturing method according to the present invention.

Figure 7 is a slot drill bit according to the present invention.

Figure 8 is a cross-section through a blank from which the slot drill bit of Figure 7 is machined in a manufacturing method according to the present invention.

Referring to the drawings, the standard twist drill bits of the invention comprise a body 1 of cemented tungsten carbide or similar material bonded to a layer 2 of PCD or PCBN. An example of a suitable PCD is SYNDITE, a product of the De Beers Industrial Diamond Division (SYNDITE is a Registered Trade Mark of De Beers Industrial Diamond Division). The layer of PCD or PCBN is of substantially uniform axial thickness and extends across the top surface of the tip of the drill bit from the centre of the tip of the drill bit 3 to approximately the distal edge 4 of the tip of the drill bit. This configuration results in a cutting edge at the tip of the drill bit 5 (sometimes referred to in the art as a cutting lip) that is composed of PCD or PCBN, the thickness of the PCD or PCBN underlying the cutting edge being substantially uniform along the cutting edge. The thickness of the PCD or PCBN layer may be chosen so as to optimise the toughness and durability of the drill bit, and is typically 0.1 to 2 mm and preferably 0.5 to 1.5 mm.

It will readily be appreciated that, in the twist drill bit of the invention, the substantially uniform thickness of the PCD or PCBN layer at the cutting edges enables repeated resharpener of the tool. Furthermore, the thickness of the PCD or PCBN layer can be chosen so as to optimise the toughness of the cutting edges. In addition, the limited thickness of PCD or PCBN layers that can be made by existing technology does not impose a limitation on the diameters of the drill bits of the invention. It will also be appreciated that it is straightforward to machine the drill bits of the invention to the optimised configuration for a twist drill bit, or to other desired configurations.

Optionally, the body of the drill bit may be in two or more parts joined together by brazing or other joining means. For example, the tip of the drill bearing the PCD or PCBN layer 6 may be brazed to another piece of the body 7 that forms the shank of the drill bit.

The twist drill bit of Figure 5 is machined from the cylindrical blanks having a conical pointed tip of Figure 6. The cross-sectional angle of the conical pointed tip (the tip angle) may be approximately  $118^\circ$ , the optimum cross-sectional angle for the tip of the finished drill. The cylindrical drill blank comprises a body 8 of cemented tungsten carbide or similar material having a layer of PCD or PCBN 9 in approximately a shape of a hollow cone of substantially uniform thickness extending from the centre of the tip of the drill to approximately the distal edge of the tip of the drill. The thickness of the PCD and PCBN layer is typically 0.1 to 2.0 mm, and preferably 0.5 to 1.5 mm. The twist drill bit of Figure 5 is made from the drill blank by machining the body and PCD or PCBN layer of the drill blank as a whole into the desired shape for the twist drill bit. This machining may be carried out by grinding with diamond grinding wheels or by electric discharge machining or by other methods known in the art for the machining of very hard and wear-resistant materials.

The blanks for the manufacture of the twist drills of the invention are made by subjecting a layer of diamond

powder or cubic boron nitride powder combined with a suitable catalyst-solvent onto the appropriate area of the surface of a tungsten carbide body of the tool blank in a suitably shaped mould to high temperature and pressure.

5 The PCD or PCBN layer is thus formed *in situ*, bonded to the appropriate area of the surface of the body of the tool blank. A method of manufacturing PCD layers bonded *in situ* onto shaped cemented tungsten carbide bodies in disclosed, for example, in European Patent Application No.  
10 89308730.4 (De Beers Industrial Diamond Division (Proprietary) Limited) filed on 30th August 1989.

Typically, the requirements of the high temperature, high pressure apparatus mean that a PCD or PCBN layer is bonded in the bonding step to only a part of the body of the  
15 blank 10, corresponding to the tip of the finished drill. The part of the blank with the PCD or PCBN layer bonded to it is then attached to the remainder of the body of the blank 11 by brazing or other appropriate means.

The slot drill of Figure 7 comprises a body 12 of  
20 cemented tungsten carbide or similar material bonded to a layer of PCD or PCBN 13. The layer of PCD or PCBN extends across the top surface of the tip of slot drill and some distance down and around the sides of the slot drill below the tip, whereby the cutting edges of the slot drill are  
25 substantially composed of PCD or PCBN.

Optionally, the body of the slot drill bit may be in two parts joined together by brazing or other joining means. For example, the tip of the slot drill bit bearing the PCD or PCBN layer (14) may be brazed to another piece of the  
30 body (15) that forms the shank of the slot drill bit.

The slot drill bit of Figure 7 is manufactured by machining it from the cylindrical blank of Figure 8. The blank comprises a body of cemented tungsten carbide or similar material 16 and a layer of PCD or PCBN 17 of  
35 substantially uniform thickness and approximately in the form of a cup surrounding and bonded to the top part of the body. The thickness of the PCD or PCBN layer is typically between 0.1 and 2.0 mm, and preferably between 0.5 and 1.5

mm. The slot drill bits of the invention are made from the blanks by machining the body and the PCD or PCBN layer of the drill blank as a whole into the desired shape for the slot drill bit. This machining is carried out as described

5 above.

The blanks for the manufacture of the slot drill bits of the invention according to the process of the invention are made as described above by use of a suitably shaped tungsten carbide body and mould in a high temperature, high  
10 pressure synthesis step. The blanks may comprise two or more pieces brazed together as described above.

It will be readily apparent to persons skilled in the art that the other tool bits of the invention can be made by variations of the methods of manufacture described above.

15

CLAIMS

1. A twist drill bit comprising a layer of PCD or PCBN of substantially uniform axial thickness extending over  
5 substantially the whole top surface of the tip of the drill bit.
2. A twist drill bit according to claim 1 in which the PCD or PCBN layer is bonded to a drill bit body  
10 comprising cemented tungsten carbide, cemented tantalum carbide or cemented titanium carbide.
3. A twist drill bit according to claim 1 or 2 wherein the drill bit comprises two or more pieces joined  
15 together by brazing.
4. A twist drill bit according to any of claims 1-3 wherein the diameter of the drill bit is greater than 2mm.
- 20 5. A twist drill bit according to any of claims 1-4 wherein the diameter of the drill bit is greater than 5mm.
6. A twist drill bit according to any of claims 1-5 wherein the axial thickness of the PCD or PCBN layer is  
25 between 0.1 and 2.0mm.
7. A twist drill bit according to any of claims 1-6 wherein the axial thickness of the PCD or PCBN layer is between 0.5 and 1.5mm.  
30
8. A twist drill bit according to any of claims 1-7 wherein the tip angle is approximately 118°.
9. A slot drill, end mill, thread tap or reamer  
35 comprising a layer of PCD or PCBN bonded to a convex curved surface of a tool body, which layer is shaped to provide a cutting edge composed of PCD or PCBN.

10. A slot drill, end mill, thread tap or reamer according to claim 9 wherein the thickness of the layer of PCD or PCBN, when measured in a direction perpendicular to the axis of the tool body, does not exceed 2.0mm.

5

11. A slot drill, end mill, thread tap or reamer according to claim 9 or 10 wherein the tool body comprises cemented tungsten carbide, cemented tantalum carbide or cemented titanium carbide.

10

12. A slot drill, end mill, thread tap or reamer according to claim 9, 10 or 11 wherein the slot drill, end mill, thread tap or reamer comprises two or more parts joined together by brazing.

15

13. A method of manufacturing a twist drill bit comprising the steps of:

providing a tool blank body having a conical tip;

20 fabricating a drill blank by bonding a layer of PCD or PCBN to substantially the whole surface of the conical tip, said layer having substantially uniform axial thickness; and

machining the drill blank into the twist drill bit.

25

14. A method of manufacturing a twist drill bit according to claim 13 wherein the drill blank body comprises cemented tungsten carbide, cemented tantalum carbide or cemented titanium carbide.

30

15. A method of manufacturing a twist drill bit according to claim 13 or 14 wherein the axial thickness of the layer of PCD or PCBN is between 0.5 and 1.5mm.

35 16. A method of manufacturing a twist drill bit according to claim 13, 14 or 15 wherein the diameter of the finished drill is at least 5mm.



17. A method of manufacturing a twist drill bit according to claim 13, 14, 15 or 16 wherein the drill blank is attached to a shank by brazing or other means prior to machining the drill blank and PCD or PCBN layer.

5

18. A method of manufacturing a slot drill, end mill, thread tap or reamer comprising the steps of:

providing a suitably shaped tool blank body;

10 fabricating a tool blank by bonding a layer of PCD or PCBN to a convex curved surface of the body; and

machining the tool blank to form the slot drill, end mill, thread tap or reamer.

19. A method according to claim 18 wherein the tool  
15 blank body comprises cemented tungsten carbide, cemented tantalum carbide or cemented titanium carbide.

20. A method according to claim 18 or 19 wherein the thickness of the PCD or PCBN layer is between 0.5 and 1.5mm.

20

21. A method according to claim 18, 19 or 20 wherein the body is attached to a tool shank by brazing or other means before machining the body and PCD or PCBN layer.

25

22. A twist drill bit substantially as hereinbefore described with reference to the accompanying drawings.

23. A slot drill, end mill, thread tap or reamer substantially as hereinbefore described with reference to  
30 the accompanying drawings.

24. A method of manufacturing a twist drill bit substantially as hereinbefore described with reference to the accompanying drawings.

35

25. A method of manufacturing a slot drill, end mill, thread tap or reamer substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977  
 Examiner's report to the Comptroller under  
 Section 17 (The Search Report)

Application number

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Relevant Technical fields

(i) UK CI (Edition K ) B3C; B3K; E1F (FGA, FFP)

(ii) Int CI (Edition 5 ) B23C; B23D  
 B23B;

Databases (see over)

(i) UK Patent Office

(ii) ONLINE SEARCH: WPI

Search Examiner

R HOWE

Date of Search

9 OCTOBER 1991

Documents considered relevant following a search in respect of claims 1-8, 13-17, 22, 24

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0223585 A2 (SUMITOMO ELECTRIC)	at least 1
X	US 4764434 (ARONSSON) see Figure 3	at least 1

Category	Identity of document and relevant passages	Relevant to claim

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